AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

SPACE ACTIVITIES OF WESTERN EUROPE

MAJOR ARTHUR V. HARRIOTT 86-1070

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PREFACE

For the first two decades after the start of the space age, the United States and the Soviet Union dominated most areas of space activity and monopolized the field of space launchers. Today, the nations of Western Europe engage in dynamic programs to design, develop, and operate launch vehicles and satellite systems. Despite Europe's emergence as a space power, most writings of the 1980s tend to focus on the space activities of the two superpowers and on their long-standing competitive relationship. A search of available literature found no single source describing the diverse space activities of Western Europe, how the Europeans fund and manage their broad array of sophisticated projects, and the future directions of Europe's space activities. This paper presents an overview of those activities, from Europe's entry into the space arena through her plans for the rest of this century.

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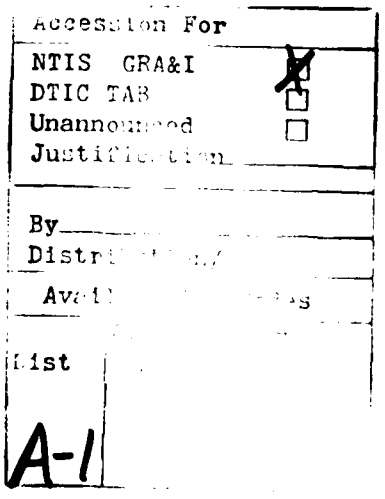

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Major Arthur V. Harriott was [redacted] and earned a Bachelor of Science Degree in Mathematics from Northern Illinois University. He was a distinguished graduate of the Air Force Officer Training School and has extensive experience in the development, testing, and maintenance of space surveillance and missile warning system computer software. While assigned to Headquarters Space Command, Major Harriott played a key role in the acquisition of satellite and space shuttle command, control and communication systems being developed for the new Air Force Consolidated Space Operations Center. His military decorations include the Air Force Commendation Medal, the Joint Service Commendation Medal, and the Defense Meritorious Service Medal with one Oak Leaf Cluster. Major Harriott holds a Master of Arts Degree in Computer Resource Management from Webster University, St. Louis, Missouri.

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EXECUTIVE SUMMARY

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Chapter One

INTRODUCTION

The 25 year domination of space activity by the U.S. and U.S.S.R. is over. The nations of Western Europe, collectively through the European Space Agency (ESA), conduct highly successful programs in the fields of space science, space launch, and applications satellites such as remote sensing, navigation, and telecommunications. Furthermore, ESA has ambitious plans to expand Europe's space programs into the twenty-first century. Slightly more than ten years after the formal establishment of ESA in May 1975, Europe has become both a valuable partner to the United States in cooperative space ventures and an important competitor in the international market for space technology and launch services (50:5). Extensive interaction therefore seems inevitable between the U.S. and Western Europe in the development of future space systems and in their operation. Because of this interaction, we need to understand ESA and how it conducts Europe's space activities.

This paper is intended to provide insight into ESA and the diverse space programs in which the agency and its member states are engaged. Previous studies of European space activities offer detailed descriptions of projects and analyses of U.S. policy alternatives for international cooperation and competition in space. This paper is purposefully limited in scope to provide a succinct, single source reading on the background, function, and future plans of ESA.

Chapter Two of this paper discusses ESA's background, showing how the agency and its programs evolved from previous European space organizations. A synopsis of U.S.-European interaction during ESA's formative years is included to illustrate the impact of American space activities on those of Europe.

Chapter Three summarizes the purpose and mode of operation of ESA and highlights some of the major space activities Europe plans for her next two decades.

Chapter Two

EVOLUTION OF EUROPEAN ORGANIZATION FOR SPACE

Following successful satellite launches by the Soviet Union and the United States in 1957 and 1958, European scientists and politicians realized the growing disparity between European space activities and those of the two superpowers. They began to consider space technology as an area with great potential to stimulate European industrial and economic development, and feared dire consequences for their technological and industrial futures if they failed to get involved in the space age (8:24). Individually lacking the financial resources and industrial bases to support significant space programs on their own, several European nations recognized that they could mount substantial efforts only by combining their resources (49:235).

Differing views emerged, however, on priorities for projects and funding and regarding the direction a cooperative European space program should take. The scientific community and many of the smaller countries with more limited financial resources were primarily interested in basic research and space exploration. They had little interest in development of a European launch vehicle, fearing such a program would be too costly and would preclude funding of research projects (7:223). These nations also questioned the necessity of a European launcher because they felt U.S. launch vehicles would be adequate to their needs and American offers to launch Europe's satellites could be depended upon (49:235). Other Europeans, most notably the French, envisioned a more comprehensive space program encompassing basic research, application satellites, and launch vehicles. These countries argued that a European launch capability, independent of the United States, was vital to their space program and that the U.S. might refuse to launch a European payload if it threatened to compete with American interests (52:67).

This divergence of opinion led to the formation of several cooperative agencies in the early 1960s. First, the Conference Européene de Telecommunications par Satellites (CETS) was formed in May 1963. The charter of this European inter-governmental agency was to present a unified European position in the negotiations of the International Telecommunications Satellite Organization (INTELSAT). CETS dissolved after fulfilling its mission in 1971, with the completion of arrangements for the final INTELSAT regime (49:236). Two other space cooperatives began operation in 1964, and

continued functioning until 1975. The European Space Research Organization (ESRO) was founded to further space research, and the European Launcher Development Organization (ELDO) was formed to field a European launch vehicle. More information on the activities of ESRO and ELDO is presented later in this chapter.

From their formation, ESRO, ELDO, and CETS pursued their respective interests largely in isolation from each other. In 1966, Europeans sought to give cohesion to their space activities by establishing the European Space Conference (ESC). With membership comprised of representatives from ESRO, ELDO, and CETS; ESC functioned to coordinate the various European space activities and seek efficiencies in the use of manpower and funds (49:292). Differing national interests and priorities among ESC members, however, continued to make a truly unified European space program unachievable. A consensus had existed within ESC from its beginning that all European space organizations should be merged into a single agency. Discussions throughout the late 1960s and early 1970s focused on disagreements over the relative weight to be given three program areas: science, applications, and launch vehicles. Resolution finally came in mid-1973 in the form of a compromise whereby France, West Germany and the United Kingdom (U.K.), the three largest participants, agreed to a reciprocal support arrangement for each others' preferred programs. This settlement opened the way for the establishment of the European Space Agency, which began functioning on 31 May 1975 as the sole coordinating body for the national and joint space activities of its member countries (52:362-363).

ESA began life in mid-1975 with a "full plate" of space programs to fund and manage. The following sections summarize the more important projects and issues as they developed during the tenure of ESRO and ELDO.

ESRO-SUMMARY OF SIGNIFICANT EVENTS

Formal discussions among Europeans interested in a cooperative space research program began early in 1959. The deliberations of various committees and study groups meeting from April 1959 through May 1962 culminated in a document entitled, The Convention for The Establishment of a European Space Research Organization. Formal ratification of the document took until March 1964, by which time Belgium, Denmark, France, Germany, the Netherlands, the U.K., Spain, Sweden and Switzerland had signed as full members of ESRO and Austria and Norway had observer status. Italy became a member when it ratified the convention later in 1964 (51:453-454).

The ESRO Convention stated the purpose of the organization in Article II: "To provide for, and to promote, collaboration among European states in space, research and technology, exclusively for peaceful purposes" (49:238). To fulfill this purpose Article V laid out program guidance for ESRO which included design and construction of sounding rocket payloads, satellites, and space probes; procurement of launch vehicles and facilities; and provision of the means to collect and analyze data. The program plan also directed ESRO to support research and development efforts needed for its programs (51:454-455).

ESRO embarked immediately on its scientific program, launching 168 sounding rockets between 1964 and 1972. Most of these were for studies of atmospheric and ionospheric phenomena. ESRO cancelled its sounding rocket program in 1972 (49:251-254). ESRO also successfully orbited seven scientific satellites from May 1969 to November 1972 (49:Table 3), all of which were launched for them by the United States. In addition, COS-B, a gamma radiation study satellite, was ready for launch and four other scientific satellites were under development when ESA took over ESRO's functions in 1975 (7:237).

By the mid-1960s the importance of space applications had become apparent to the Europeans (51:475), and in November 1966 CETS requested that ESRO do a six-month study on experimental television distribution satellites. This study showed that Europe had the technological capability to develop such a satellite. But the existence of three separate space organizations made the decision process cumbersome and no applications programs were started (49:290-292; 51:467-477). As pointed out above, even after the formation of ESC in 1966, consensus among European nations and space agencies remained difficult to achieve. However, ESC set up a working group in 1969 to study the feasibility of a European communications satellite program. The effort involved representatives of ELDO, ESRO, the European Broadcasting Union (EBU), and the European Conference on Postal and Telecommunications Administration (CEPT). Recommendations of the study group resulted in major reform in ESRO in 1971, wherein funding was greatly reduced for scientific programs. ESRO shifted its emphasis to space applications, and between 1971 and 1974, started four applications projects (49:260). These were the Orbital Test Satellite, METEOSAT, MAROTS, and AEROSAT.

ESRO approved the Orbital Test Satellite (OTS) project in 1971 as an experimental step toward development of an operational European telecommunications system (7:237). OTS was launched aboard a U.S. Delta rocket in 1978. In that same year, ESA approved the European Communications Satellites (ECS), a five-satellite constellation intended to serve regional communications needs for the ensuing ten years (52:178).

The METEOSAT Program, approved by ESRO in 1972, called for the development of a geostationary orbiting satellite to provide imagery of Europe, Africa, and the Mediterranean for weather forecasting. The U.S. launched METEOSAT 1 on a Thor-Delta booster in 1977 and France launched the follow-on METEOSAT 2 in 1981 on the third test flight of the Ariane 1 vehicle (52:179; 50:115).

In 1973, ESRO added the MAROTS project to its optional program. MAROTS included two satellites, based on the OTS design, to provide maritime navigation and ship-to-ship communications services (7:235, 237). The program was later renamed MARECS with the satellite designs resembling the ECS that had evolved from OTS (52:178). France launched MARECS A in December 1981 on the fourth Ariane 1 test flight. An attempt the following September to launch MARECS B on an Ariane 1 failed and MARECS B2 reached geosynchrous orbit in November 1984 aboard Ariane 3 (50:115).

AEROSAT began in 1974 as a joint European/U.S./Canadian project to develop an experimental air traffic control, navigation and communications system (7:237). The project was cancelled in 1977 when the U.S. Federal Aviation Administration withdrew because of fund shortages (52:186).

During the 1971 ESRO reform an important change took place in the method of funding space projects. Due to the number and magnitude of projects being undertaken, ESRO implemented the method often referred to as "a la carte" financing (49:246). Under this scheme, all members were required to support the organization's basic program, consisting of the ESRO operating costs and science program, on a scale proportionate to their countries' gross national products. In addition, members were allowed to select those special projects in which they wished to participate. Funding for special projects however, was determined by the same scale used to compute members' shares of the compulsory program This limited, to some extent, the flexibility members had in signing up for a variety of projects they were interested in (49:246,260). ESRO modified the system in 1973 to allow nations, including non-members, to contribute to optional programs amounts determined by their own levels of interest. This scheme allowed greater flexibility for states to choose programs and enabled smaller countries to participate in more projects, thus increasing sources of capital (49:261). This is the same funding mechanism used currently by ESA to finance its optional programs.

A final development worthy of note concerns the use of industrial consortia which began during ESRO's operation. During the late 1960s, European aerospace and electronics firms organized consortia to assemble the needed mixes of disciplines to submit competitive bids for ESRO projects. These consortia were multinational and thus served to spread contracts and sub-contracts

throughout the ESRO nations (7:228; 4:648-649). ESA continues to do most of its business with industry consortia as do the individual countries for their national space projects. The composition of each consortium varies with the nature of the project at hand and occasionally includes one or more American firms. A recent example is the consortium led by France's Aerospatiale and the United States' Ford Aerospace for development of the ARABSAT communications satellite (14:137).

ELDO-SUMMARY OF SIGNIFICANT EVENTS

Discussion of the possibility of building a European launcher began as early as 1959 among the British when they abandoned their Blue Streak missile project as a military weapon (44:110) and suggested it as a first stage for an orbital launch vehicle (15:267). The idea was favorably received among Europeans and meetings of government and industry representatives ensued through 1960-61. The discussions culminated in agreements to build a vehicle for which the U.K. would provide the Blue Streak for the first stage, France would develop the second stage, and West Germany would build the third stage (51:484-485). Related discussions resulted in the drafting of The Convention for the Establishment of a European Organization for the Development and Construction of Space Vehicle Launchers, generally known as the ELDO Convention. The Convention was signed on 29 March 1962 by Australia, Belgium, France, Germany, Italy, the Netherlands and the U.K. Following ratification by all involved governments, the Convention entered into force on 29 February 1964 (49:265).

From the outset, considerable doubt existed among members of the new organization as to the adequacy of the projected costs to develop the launcher (51:485). The program was plagued by numerous proposals to alter designs, increase lift capability, and develop follow-on vehicles. During this debate, the ELDO Launcher (later known as ELDO A, then EUROPA) was failing launch tests (7:236) and experiencing schedule slips and escalating costs (49:267-276). In 1966, the U.K. first began to question whether the launcher under development would prove to be obsolete before it was fielded. One of ELDO's aims had been to capture some of the INTELSAT business, launching communications satellites for members of that international organization (15:57-58). The U.K. questioned whether EUROPA would be competitive with U.S. launchers (5:321-322). In April 1968, the U.K. announced its intent to withdraw from ELDO, due largely to continually rising costs of EUROPA. The British ministers indicated the country would honor her present financial commitments to ELDO through 1971 but would support no new programs or proposed modifications to EUROPA (51:494-496).

The withdrawal of the U.K. meant that France and Germany, the other principal financial backers of EUROPA, had to pick up the slack if the program was to continue. The U.K. had commited to provide 27 percent of the project's funding. Italy, which had signed up for 12 percent, also withdrew its support as did Australia, whose contribution had been the launching and test facilities at Woomera. During re-negotiations in January 1971, Belgium and the Netherlands increased their aggregate 9 percent contribution modestly to 9.7 percent, Germany raised its share from 27 to 47 percent, and France increased its subscription from 25 to almost 43 percent. The French also stepped up efforts to construct their equatorial launch site at Kourou, French Guiana, South America (51:491-502).

The French and Germans proposed a multitude of redesigns for EUROPA throughout 1971-72 (11:1171; 29:400; 31:85-86; 26:83-84). By the end of 1972, EUROPA had evolved to the L3S, a three-stage vehicle proposed by France to meet Europe's needs to place satellites in orbit (38:20; 21:19). Further revisions of the initial French design were considered and by the end of February 1974, participating ELDO members signed new agreements to develop a vehicle christened Ariane. Under the new terms, France was to put up over 60 percent of the financing and Germany would pay 20 percent with the remainder to be allocated among other interested countries (39:34-35; 1:293; 2:375).

Thus, as ESA prepared in 1975 to take responsibility for conducting and coordinating Europe's space activities, its ministers faced a diverse agenda of scientific missions and applications satellites from ESRO and a launcher development program from ELDO. One of the most important issues ESA would confront, however, resulted from a U.S. initiative that ESRO, ELDO, and the ESC had been wrestling with since 1969.

U.S.-EUROPEAN INTERACTION

The late 1960s and early 1970s were years of intense activity and change in Europe's space programs: An active scientific program developed and continued to grow; major initiatives got underway in various applications satellite fields; a launcher development effort began and later took new direction; and organizations changed in form and function as Europeans sought ways to fund, manage, and integrate their programs. As much of this activity was nearing its height in 1969, NASA Administrator Thomas O. Paine approached ESC members regarding European participation in the U.S. post-Apollo program (49:37-38).

The post-Apollo program was not well defined in 1969, but NASA envisioned an ambitious undertaking which included a large permanent manned space station, a fully reusable space shuttle to place payloads in low earth orbit, one or more "space tugs" to transfer satellites from low earth orbits to geosynchrous orbits,

and "sortie modules" (later named Spacelabs) to be carried in the shuttle cargo bay for conducting scientific experiments (49:31). In August 1969, while studies were underway in the U.S. to determine the scope of the post-Apollo effort, Dr. Paine briefed European space officials on the entire program then being considered. NASA formally invited the Europeans to take part in the post-Apollo program in October 1969. In follow-on discussions, the U.S. left it largely open to ESC to decide the nature and extent of their participation, stating only that NASA wanted a significant commitment from Europe, on the order of 10 percent of the total program (12:870-871; 49:32-34).

Ambassador R. di Carrobio, then Secretary-General of ELDO, summed up European reaction to the initial NASA offer:

> ...the Committee of Senior Officials considered it of great importance because if it were to come to fruition it would radically modify all space activity....it appeared appropriate immediately to carry out a thorough inquiry into the various aspects of the program...and to maintain the closest contact with NASA (51:516-517).

Europe's space organizations immediately set in motion a variety of studies: ESRO examining possible involvement in space station and sortie module development and ELDO focusing on building the space tugs (49:49; 12:871). However, a dilemma confronted Europeans attempting to decide on collaboration in the NASA program. By their own estimates, a 10 percent contribution to post-Apollo activities would cost Europe approximately one billion dollars spread over ten years. This figure corresponded roughly to European estimates of the costs to continue developing their own launch vehicle. Thus, most ESC members felt they could only commit to 10 percent participation if they gave up their EUROPA program (51:521,506), and this in turn would require stronger assurances that the U.S. would launch Europe's satellites.

American launch assurances, however, were not unequivocal. Since 1964, the U.S. had had treaty obligations to protect the international communications satellite system of INTELSAT from competition (49:365). U.S. policy supporting a single worldwide system was based on technical, economic, and social reasons:

> Technically, a single system provides the most effective use and management of the limited frequency spectrum, avoids duplication of and interference between competing systems, improves operating efficiency, and reduces the technical and operational problems of compatibility between different space systems and other services. From the economic standpoint the single system provides an orderly framework for improving and expanding the communications facilities of all nations, both spatial

> and terrestrial, with minimum drain on scarce resources. Finally, the single system facilitates mutually desired educational and cultural exchanges--demonstrating that the inherent social and economic benefits of space communications are available to all on a non-discriminatory basis (51:442).

As mentioned above, Europeans had long had an interest in developing a regional communications satellite system. ELDO Secretary-General di Carrobio described the European's concern:

> This difficulty is that the American policy as formulated cannot specify whether or not Europe could rely on launchers for public service operational communications satellites even if their operation were limited to the European Zone. The resolution of this problem would rest, in part at least, on votes taken in the assembly of INTELSAT. This would have to be the first substantial point of any future negotiation (51:521).

Europeans were also uneasy about the lack of definition of the post-Apollo program in the early 1970s. The suggested 10 percent commitment was nearly equivalent to the total annual subscription of European nations to ESRO. Even a minor cut to NASA's budget for the post-Apollo project could have a disastrous impact on Europe. The Europeans decided, therefore, to go forward with their current projects through 1970-71 while continuing studies and negotiations to determine their post-Apollo role (12:870).

However, the question of collaboration with the U.S. added another key issue to ESC's list of problems to solve (7:233). It compounded ongoing disagreements over the allocation of funds among programs and added a major factor to considerations of whether or not to continue with EUROPA (51:506). The post-Apollo question increased the awareness of many in Europe of the need to consolidate European space organizations into "...an amalgamation of ELDO and ESRO--a sort of European NASA" (12:871). As the U.S. later refined its post-Apollo program, the question of Europe's participation unfortunately became one of the contentious issues that delayed the formation of ESA.

NASA lowered its sights considerably for the post-Apollo project when the agency experienced severe budget reductions for fiscal years 1970 through 1972. After a series of industry studies, NASA settled on the thrust-assisted-orbiter shuttle (TAOS) system. This configuration called for a reusable shuttle vehicle, two recoverable solid-fuel rocket boosters (SRB), and an expendable external tank (ET). This system would be capable of launching payloads of 65,000 pounds to low earth orbit (40:13). NASA planned to use existing hardware to build an interim space tug to boost the

payloads to higher orbits, and would develop a reusable tug later (33:104). President Nixon approved the space shuttle development plan in January 1972 (49:36-37).

In talks with ESC during early 1972, NASA began to encourage European development of the sortie modules while de-emphasizing the space tug (13:332). By mid-1972, the U.S. withdrew the tug offer completely, citing as reasons the uncertain definition of the tug and lack of U.S. commitment to proceed with its development (46:14). The United States further restricted the offer of participation in shuttle construction to a few structural items, and strongly encouraged Europe to develop the sortie module as its independent segment of the post-Apollo program (25:322). The American officials also stipulated that Europe's management practices would have to be tightened considerably if she were to participate in the program in any major way. This latter condition was seen by some observers to emphasize Europe's need to unify her space programs and organizations (37:103).

A number of Europeans had come to view the space tug as the most promising area for their participation in the U.S. post-Apollo program. Tug development seemed to offer the greatest potential to stimulate technological advancement in European industry. Of the options initially discussed with NASA, Europeans believed the tugs would generate the most business for their aerospace industries and, hence, the most revenue for their economies. Also, development of the tugs offered the best assurance of continued involvement in manned space activities because the tugs would be considerably more integral to NASA's future programs than Spacelab (12:870).

Many Europeans were discouraged by the U.S. withdrawal of the tug offer and felt Europe was being relegated to developing only normal technology. In view of perceived diminished financial and technological returns, some began to question the benefits to Europe of any collaboration in U.S. space activities (18:19; 16:22). ESC debated the issue of post-Apollo participation for the remainder of 1972. Central to the debate were the positions of the three largest contributors to ESRO and ELDO; Germany, France, and the U.K. Germany favored Spacelab development, feeling that technological and industrial benefits would accrue to Europe through involvement in NASA's manned program. The Germans did not believe, however, that Europe could afford continued development of the L3S launcher along with Spacelab development (48:17; 10:16). France lost interest in post-Apollo participation when the space tug was withdrawn, and remained committed to construction of the European launch vehicle (10:17). The U.K. also cooled toward the U.S. program because it saw little technological or financial payoff to Europe from Spacelab. The U.K. was primarily interested in the formation of a single European space organization and in developing its Geostationary Technology Satellite (GTS), an experimental maritime communications satellite (45:23, 17:22).

Negotiations among ESC members remained at an impasse through the first half of 1973 with Germany, France, and the U.K. unable to agree among themselves and with other European nations on funding for each of their favored programs. These disagreements also stalled progress in the discussions of a unified space agency (34:680). ESC finally met in July 1973 following a lengthy series of negotiations, and formally agreed to a "package deal" consisting of Spacelab development, L3S launcher construction, and development of an ESRO experimental maritime satellite named MAROTS (7:234).

The compromise that was reached consisted mainly of each of the major participants bargaining its support for others' projects in return for their support of its own favored project. The U.K. reversed its earlier position against further funding for launcher development and agreed to help fund L3S. The U.K. also dropped its national GTS program and became team leader for ESRO's MAROTS program. France agreed to contribute to MAROTS and Spacelab and take primary responsibility for L3S development. Germany would provide the majority of the funds for Spacelab and contribute to L3S. The remaining ESC member nations consented to provide sufficient money to put all three programs on solid financial ground (49:302; 9:15-16). In September 1973, NASA and ESRO signed a memorandum of understanding calling for European design, development, manufacture, and delivery of the Spacelab module and related instrument pallets (49:64, 579-586). The Spacelab, MAROTS, and L3S (later named Ariane) projects would consume the majority of Europe's space expenditures through the remainder of the 1970s (49:302).

With these program decisions settled, ESC members were finally able to pursue the agreements necessary for creation of ESA. The new organization would assume responsibility for all ongoing ESRO programs plus the new "package deal" (9:16). ESC set a target of 1 April 1974 for establishment of ESA, but as pointed out earlier in this chapter, the ESA Convention didn't formally enter into force until May 1975, when all ten founding member states completed ratification. The amalgamation of space organizations into ESA would provide the template for European space activities up to the present time.

Chapter Three

ESA AND EUROPE'S SPACE ACTIVITIES

The European nations today develop and operate a wide variety of space systems. Individual states conduct national programs, joint projects with nations inside and outside Europe, and cooperative programs under the auspices of the European Space Agency. The task of coordinating the several national and cooperative activities falls to ESA. Articles of the ESA Convention describe the agency's purpose and mode of operation. Following an overview of the more important articles, a synopsis of some of the current and planned activities of ESA's members will indicate the magnitude of the agency's task.

THE EUROPEAN SPACE AGENCY

Since its formation in May 1975, ESA has functioned as the coordinating body for European space policy and for the national space-related activities of its member states. ESA serves as the vehicle through which European countries pool their industrial resources and portions of their national space budgets to conduct cooperative space projects. Article II of the Convention for the Establishment of a European Space Agency sets forth the purpose of ESA:

> The purpose of the Agency shall be to provide for and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications...;
>
> (a) by elaborating and implementing a long-term European space policy...;
>
> (b) by elaborating and implementing activities and programs in the space field;
>
> (c) by coordinating the European space program and national programs, and by integrating the latter progessively and as completely as possible into the European space program...;

(d) by elaborating and implementing the industrial policy appropriate to its program and by recommending a coherent industrial policy to the Member States (49:587-588).

The eleven member states of ESA are Belgium, Denmark, France, the Federal Republic of Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland, and the U.K. Additionally, Austria is an associate member; Norway holds observer status; and Canada has signed a memorandum of association with the agency (50:43).

As provided for in Article V of the ESA Convention, members fund and participate in the agency's activities in two ways: mandatory activities, in which all member states participate; and optional activities, in which the states participate unless they request to be excluded. Article XIII stipulates that member contributions to the mandatory programs will be based on the average of each country's national income over the last three years with no member paying more than a quarter of the agency's mandatory program costs. ESA's mandatory elements are the agency's general operating budget and its space science program (49:588-593). Optional activities include specific programs for design, development, and operation of satellites, launch vehicles and launch facilities. Members negotiate the percentages of such projects they will fund based on each country's degree of interest in the programs (52:177).

Nearly all of the features which characterize ESA operations today were inherited from the predecessor organizations from which it evolved as Europe worked to "get its space act together." Similarly, most of the space projects in Europe's agenda for the 1980s and 90s are direct descendants of those begun by ESRO and ELDO.

EUROPEAN SPACE ACTIVITIES

In January 1985, ESA's ministers met in Rome and endorsed a comprehensive space program for the next ten years that will increase the agency's annual space budget from $800 million in 1985 to approximately $1.4 billion in 1990 (36:24). The seven-point program includes European participation in the U.S. space station project, significant expansion of launch and space transportation capabilities, a major space science program, earth observation satellites, telecommunications, microgravity research, and a technological support program to aid development of each of these efforts (22:26).

A key element of the ESA program is the development of Columbus, a complex of laboratory modules and free-flying platforms to be part of NASA's space station. Definition and preliminary design studies will be completed in early 1987 to determine the scope of the Columbus configuration more precisely (41:73). The plans West Germany and Italy jointly proposed to the ESA council include a series of pressurized modules whose design would capitalize on experience the Europeans gained during their development of Spacelab (47:72-74). The initial version of the module will extend Spacelab technology to develop a pressurized manned element of the U.S. space station. In the next phase, support systems are to be added to the module to enable it to become a free-flyer, remaining in orbit near the station. The rationale for this free-flying module is to provide a quiet environment for microgravity research where delicate experiments won't be disturbed by space station operations. Service to the module can either be performed by docking it to the station or by astronauts using Manned Maneuvering Units to fly to the Columbus module.

Near the end of the century, ESA envisions the evolution of Columbus into what will essentially be a European space station: a constellation of free-flying platforms to which one or more Columbus modules could be attached, operating in polar orbit or co-orbiting with the U.S. station. West Germany and Italy plan to lead the Columbus study efforts (referred to as the Phase B studies) contributing 37 and 25 percent, respectively, for the study funding (30:17). The U.K. intends to fund 15 percent of the Phase B effort, taking the lead in designing the free-flying platforms.

For transporting personnel and supplies to the platforms, ESA is considering a transfer orbit vehicle which could be based at the U.S. space station. The vehicle being considered for this purpose is the Hermes mini-shuttle proposed by the French space agency, Centre National d´ Études Spatiales (CNES). The reusable manned Hermes spacecraft is an important feature of ESA's plans for Europe's future space transportation program. Initial designs for the Hermes call for a vehicle 50-60 feet in length with the capacity to lift payloads up to about 9000 pounds to altitudes between 106 and 550 miles (28:11). The mini-shuttle is to carry a four to six-person crew and have the capability to remain in orbit for up to 30 days or remain docked to the space station up to 90 days (14:136). Hermes is presently a French national program but the ESA council of ministers is interested in including it in the agency's agenda of optional programs as soon as feasible (36:24).

Another reusable shuttle-type vehicle being considered for adoption by ESA is the British horizontal take-off and landing launcher, HOTOL (30:16). This single-stage-to-orbit vehicle is under study by the U.K. with a target date for operation around the year 2000 (14:136). Plans call for an orbiter about 150 feet

long with a 50 foot wingspan to place payloads of up to seven metric tons (15,432 lbs.) into low earth orbits of approximately 300 kilometers (23:19). The HOTOL is to be powered by hybrid rocket engines which will use oxygen from the atmosphere and liquid hydrogen for low altitude flight, switching to onboard oxygen and hydrogen at higher altitudes. Originally conceived as a remotely piloted unmanned vehicle, the HOTOL could carry a manned module if necessary (6:357).

The largest single project among ESA's optional programs (50:71) and the main element of Europe's space launch capability is the Ariane family of launchers. The Ariane 1, 2 and 3 family began development flights in late 1979 and commercial satellite launches in 1984. ESA intends to place the follow-on Ariane 4 into operation in 1986 (50: Table 5-1; 35:338). The Ariane 1, 2 and 3 boosters give Europe the capability to place payloads of four to five thousand pounds into geostationary transfer orbits from which they are usually moved to circular geosynchronous orbits with the aid of apogee motors. Ariane 4 will increase Europe's payload lift capacity to about 9,200 pounds (42:172-173).

By the mid-1990s, ESA plans to phase out the current Ariane versions and begin operations with the new Ariane 5. This heavy lift booster will give Europeans the ability to launch shuttle-size satellites and will have a total payload capacity of over fifteen tons (20:477; 35:337). Design studies already under way are focused on development of the large cryogenic engines needed for Ariane 5. France is the lead nation for the Ariane program and provides more than half of its funding. West Germany and Italy are other major contributors, funding 20 percent and 15 percent, respectively (30:17). France has developed six potential versions for Ariane 5 to allow for a variety of payload lift options. Differences in configuration are concentrated mostly in upper stage assemblies, where variances in upper stage power and payload fairings allow the flexibility to inject one, two, or three satellites into low earth, transfer, or geosychronous orbits as mission needs dictate (19:69). One configuration under study allows for Ariane 5 to be man-rated in order to carry the Hermes mini-shuttle (36:24). The French are also considering designs which include recoverable stages, such as solid rocket bodies, and plan to begin studies in 1987 toward a reusable launcher to enter service after 2010 (20:477).

Development of Ariane and operation of the Kourou, French Guiana spaceport from which they are launched are responsibilities of ESA and the French space agency, CNES. However, the production, marketing and operation of Ariane are not. In 1980, France formed Arianespace, a quasi-private corporation, to build, market and launch the Ariane rockets (3:31). CNES is the largest single shareholder of Arianespace with 34 percent. European manufacturers and banks, many of which are nationally owned, hold the remaining shares (52:183). Arianespace offers commercial customers a fly no-

pay later financing plan whereby customers can wait to pay the majority of launch costs until their satellites are in orbit and generating revenues (50:132-133). Ariane has captured nearly half of the world's market for launch of commercial satellites. ESA predicts a demand of approximately 150 satellites seeking launchers in the 1987-1991 period. Their goal is to provide boosters for at least a third of that market. With the completion of a second pad at the Kourou launch site in late 1985, Arianespace expects to be able to conduct ten launches per year (24:346-347).

ESA has also continued to operate and upgrade most of the application satellite systems that were begun during the last years of ESRO's existence. These include the METEOSAT weather data system, the MARECS maritime communications satellites, and the European Communications Satellites (ECS) (22:26; 43:171). Also, European industrial consortia are developing experimental communications and television braodcast satellites, such as Olympus, which ESA plans to launch in 1987 (14:137). In the area of space science, ESA has projects under way in a variety of research fields including a Halley's Comet intercept (Giotto), interplanetary space study (Ulysses), infrared astronomy (ISO), space astronomy (Hipparcos), and remote sensing of oceans and ice zones (ERS-1) (43:171). Finally, an ESA project Europeans foresee as a major contributor to both their applications and scientific space programs is the EURECA platform. EURECA will be a free-flying retrievable carrier which can house experimental application systems, research projects and commercial ventures such as laboratories for processing materials in space. EURECA is under development by a German-led consortium and is scheduled for launch aboard the space shuttle in 1988. The first flight will carry a microgravity research experiment and an experimental communications relay system. After its six-month mission, EURECA will descend to be picked up by the shuttle for return to earth and refurbishment for a later flight (14:136-137).

In addition to the programs conducted under ESA's auspices, individual European states have national projects under way in both space science and applications. National scientific projects include Sweden's Viking satellite, for electrical, magnetic and auroral studies; and Germany's Roentgen-Satellite (ROSAT), a large x-ray telescope (43:171). France, Denmark, Italy and the U.K. are also involved in numerous space research projects in cooperation with the U.S., Japan and the U.S.S.R. (50: Table 9-1). In the area of applications, France, the U.K., Sweden and West Germany are all engaged in developmental satellite programs to provide direct broadcast television transmission to most of the European continent. Examples are the Franco-German TDF-1 and TVSAT, the British UNISAT, and the Swedish TELE-X, all of which are scheduled for launch on Ariane rockets in 1986 and 1987 (43:171; 27:211-212).

The French national program, Systeme Probatoire d´ Oberva-tion de la Terre (SPOT), is worthy of note, as it promises to be the world's first commercial earth sensing satellite service. ESA rejected SPOT during the late 1970s when France proposed it as an addition to the Agency's optional programs (20:478). CNES elected to develop the system as a commercial venture and formed a company, SPOT Image, to market the satellite data internationally. SPOT Image plans to sell its data sets to private firms and government agencies for uses such as agriculture, forestry, geology, land use studies, cartography and pollution monitoring (50:284-285).

From the foregoing description of Europe's current and planned projects, it can be seen that the European nations are actively engaged in nearly every area of space activity. Europeans recognized early that their nations needed to be part of the space age. They recognized also that significant involvement would only be possible through cooperative efforts. It is evident from an overview of Europe's activities that forms of cooperation, both intra-European and trans-Atlantic, have had significant impacts on the evolution and conduct of her space programs and space organizations. At the present time, ESA and the individual states of Europe conduct satellite and launcher programs that rival those of the U.S. and U.S.S.R. in sophistication. Their plans to develop reusable manned spacecraft and to extend Spacelab technology to construct an autonomous European space station are evidence that Europe's growth as a space power will continue well into the twenty-first century.

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